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POLLUTION OF INTERSTATE WATERS OF THE MISSISSIPPI RIVER IN THE ST. LOUIS METROPOLITAN AREA

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

February 1958

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February 1958

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FOREWORD

Following the request to the Surgeon General of the Public Health Service for a conference on Water Pollution in the St. Louis Area, it was decided that information contained in the Bi-State Development Agency Report, "Mississippi River Water Pollution Investigation, St. Louis Metropolitan Area" should be supplemented by bringing it up to date and expanding the analysis of data.

This report was prepared from data in the Bi-State report and from available information in files of interested agencies concerned with the interstate waters of the area.

F. W. Kittrell, Chief, Stream Sanitation Studies, Robert A. Taft Sanitary Engineering Center, was assigned the task of collecting and analyzing data and preparing the report.

ACKNOWLEDGMENTS

This report was made possible through the assistance of nearly a score of agencies, who provided information and data necessary to bring up to date the findings of the 1951-1952 survey which served as the basis of the Bi-State Development Agency Report.

The generous cooperation of the following agencies is gratefully acknowledged.

(1) Alton Water Company (Illinois).

(2) St. Louis Department of Public Utilities, Water Division (Missouri).

(3) St. Louis County Water Company (Missouri).

(4) East St. Louis and Interurban Water Company (Illinois).

(5) Illinois State Penitentiary, Menard Branch (Water Supply).

(6) Chester Water Department (Illinois).

(7) Missouri Utilities Company (Cape Giradeau, Missouri, Water Supply).

(8) Metropolitan St. Louis Sewer District.

(9) St. Louis Board of Public Works, Department of Streets and Sewers.

(10) St. Louis Board of Public Works, Municipal Testing Laboratory.

(11) Missouri State Employment Service, Division of Employment Security.

(12) State of Illinois, Department of Public Health.

(13) State of Illinois, Natural History Survey Division.

(14) Associated Industires of Missouri.

(15) U. S. Corps of Engineers, St. Louis District.

(16) U. S. Coast Guard.

(17) U. S. Geological Survey, Surface Water Branch.

(18) U. S. Weather Bureau, River Forecast Center.

POLLUTION OF INTERSTATE WATERS OF THE MISSISSIPPI RIVER IN THE ST. LOUIS METROPOLITAN AREA

Introduction

The St. Louis Metropolitan Area surrounds the confluence of two of America's largest rivers, the Mississippi and the Missouri. At St. Louis these two streams drain a combined area of 701,000 square miles, nearly one-fourth of the total area of the United States. As a result a nearly inexhaustible flow of water passes through the heart of the Metropolitan Area.

The Mississippi is, in fact, so large at St. Louis, and downstream, that it has gained the reputation of being practically immune to damage by pollution. This reputation is not justified, as is shown by the report of the Bi-State Development Agency, "Mississippi River Water Pollution Investigation, St. Louis Metropolitan Area," published in 1954 in cooperation with the States of Illinois and Missouri and the U. S. Public Health Service. This report followed nearly two full years of field investigation, in 1951 and 1952.

The present report draws heavily on that excellent publication for basic data, facts, and conclusions. For this report data on sources of waste have been brought up to date and additional data including especially those on bacterial quality from several water supplies, have been assembled. Additional computations, based on the 1951-1952 data on bacterial contamination, oxygen demand, and dissolved oxygen both support and supplement the conclusions of the 1954 report.

The Area

The St. Louis Metropolitan Area, for purposes of this report, coincides with the "Bi-State Metropolitan Development District," which was created by compact between Illinois and Missouri (Figure 1 of the Appendix). The District includes "the City of St. Louis and the counties of St. Louis and St. Charles and Jefferson in Missouri, and the counties of Madison, St. Clair, and Monroe in Illinois." The compact authorized the establishment of the Bi-State Development Agency of the Missouri-Illinois Metropolitan District to serve as the administrative agency for planning and development of the District.

The City of St. Louis dominates the area, with about one-half of the total 1,733,000 population (1950 census) living within the city. Much of the other half of the population lives in 170 incorporated communities.

While the area is rather heavily industrialized, it is somewhat below the national average for major metropolitan areas in this respect.

Its industries are well diversified, and include a wide variety of manufacturing processes.

Sources of Pollution

St. Louis Metropolitan Area

About 200 sewers in the Metropolitan Area discharge sewage and industrial wastes to the Mississippi River along a 35 mile stretch of the river. Of these, about three-quarters discharge from the Missouri side and one-quarter from the Illinois side.

The Bi-State Agency Report stated that the total sewered population in January 1952 was estimated to be 1,140,000, of which one-eighth was on the Illinois side and seven-eighths were on the Missouri side. It is estimated that total sewered population had increased 10 per cent by mid-1957, to a total of 1,254,000.

In 1952 the sewered population equivalent of the organic industrial wastes discharged in the area was reported to be 3,716,000, of which about one-third was produced by Illinois industries and about two-thirds by Missouri industries. The total oxygen demand of the industrial wastes thus was more than three times that of the sewage. This convenient method of comparing sewage and industrial wastes, on the basis of oxygen demand, does not account for the many other pollutional characteristics of the variety of industrial wastes discharged in the area. Other pollutional characteristics of wastes result from petroleum products, phenol-like compounds, acids, metals, heavy chemicals and other materials. It was not feasible to make a detailed survey of current industrial wastes for this report. Review of data on total employment in manufacturing in the area for 1952 and 1957 showed that the totals for the two years were very nearly the same. It is concluded that there has been no significant increase in organic industrial waste discharge since 1952.

Another source of waste is the ground garbage discharged to the river by the City of St. Louis. In the Bi-State report it was estimated that 80 tons per day, having a population equivalent of 70,000, was discharged to the river in January 1952. In mid-1957 it is estimated that 280 tons per day, with a population equivalent of about 250,000, was discharged. A portion of the increase was caused by a 45 per cent greater production of garbage in June and July than in January. The remainder of the increase resulted because of the federal regulation prohibiting interstate shipment of uncooked garbage for feeding hogs. Before adoption of this regulation about two-thirds of the garbage was sold to hog growers. Since then only about 4 to 5 per cent of the total has been sold, the rest being ground and discharged to the river.

The estimated population equivalent of organic wastes from the Metropolitan Area for midyear 1957 is shown below.

Population Equivalent of Organic Wastes

Waste	Population Equivalent
Sewage	1,254,000
Industrial	3,716,000
Garbage	250,000
Total	5,220,000

Bacterial contamination added to the river in the St. Louis Metropolitan Area may be assumed to have increased in direct proportion to the increase in sewage, or about 10 per cent.

The increase in oxygen demand, as indicated by the total population equivalent of 5,220,000 for all organic wastes, was about 6 per cent. The following tabulation gives the estimated mid-1957 percentage contributions to the total population equivalent of organic wastes by types and states.

Percentage Contributions of Organic Wastes from Metropolitan Area

	Illinois	Missouri	Total
Sewage	3.0	21.1	24.1
Industrial Wastes	24.6	46.5	71.1
Garbage	0.0	4.8	4.8
	27.6	72.4	100.0

Although supporting data are not yet available it is reported that progress has been made, since 1952, in reductions of petroleum product and phenol-like wastes.

Pollution from Upstream

Both the Mississippi and Missouri Rivers bring bacterial contamination to the St. Louis Metropolitan Area. The Missouri contributes the greater portion of this contamination from upstream. Estimates of the percentages contributed by the Missouri and Mississippi rivers and by sewage from the Metropolitan Area to the total coliform organism

("sewage bacteria") content of the Mississippi River at mile 168.0 below St. Louis during 1951-1952 are shown in the tabulation below.

Sources of Bacterial Contamination

	Per Cent of Total Coliform Organisms below St. Louis
Missouri River at St. Louis County Water Co. Central Plant	21.3
Mississippi River - Mile 202.5, above Alton, Ill.	5.7
St. Louis Metropolitan Area Sewage	73.0

The yearly average coliform organism content at the St. Louis County Water Company plant, mile 35.0 on the Missouri River, was 14,000 per 100 ml. in 1951-1952. Monthly averages ranged from 4,900 to 25,000 per 100 ml. At mile 202.5 on the Mississippi, above Alton, the yearly average MPN was 2,500 per 100 ml., with a range of monthly averages from 1,100 to 5,700 per 100 ml. The monthly averages, with corresponding values for the Mississippi River at mile 168.0, just below the Metropolitan Area, are shown in Figure 2.

Both streams bring organic materials, which cause oxygen demand, to the Metropolitan Area from upstream. Insufficient data are available for the Missouri to permit comparison of contributions of oxygen demand from the two rivers and from the Metropolitan Area.

The D.O. of the water in both the Missouri and Mississippi rivers above the Metropolitan Area at times is relatively low by comparison with that of unpolluted streams. This occurs most frequently in June and July, with average monthly D.O. saturation dropping as low as 80 per cent in both streams. Each stream occasionally has D.O. concentrations slightly lower than 5 ppm.

Damages to Water Uses by Pollution

The following sections describe the effects of pollution on the significant water uses in and below the St. Louis Metropolitan Area.

Domestic Water Supplies

Public water supplies are universally accepted as having top priority on use of available sources of water. Two water plants in the

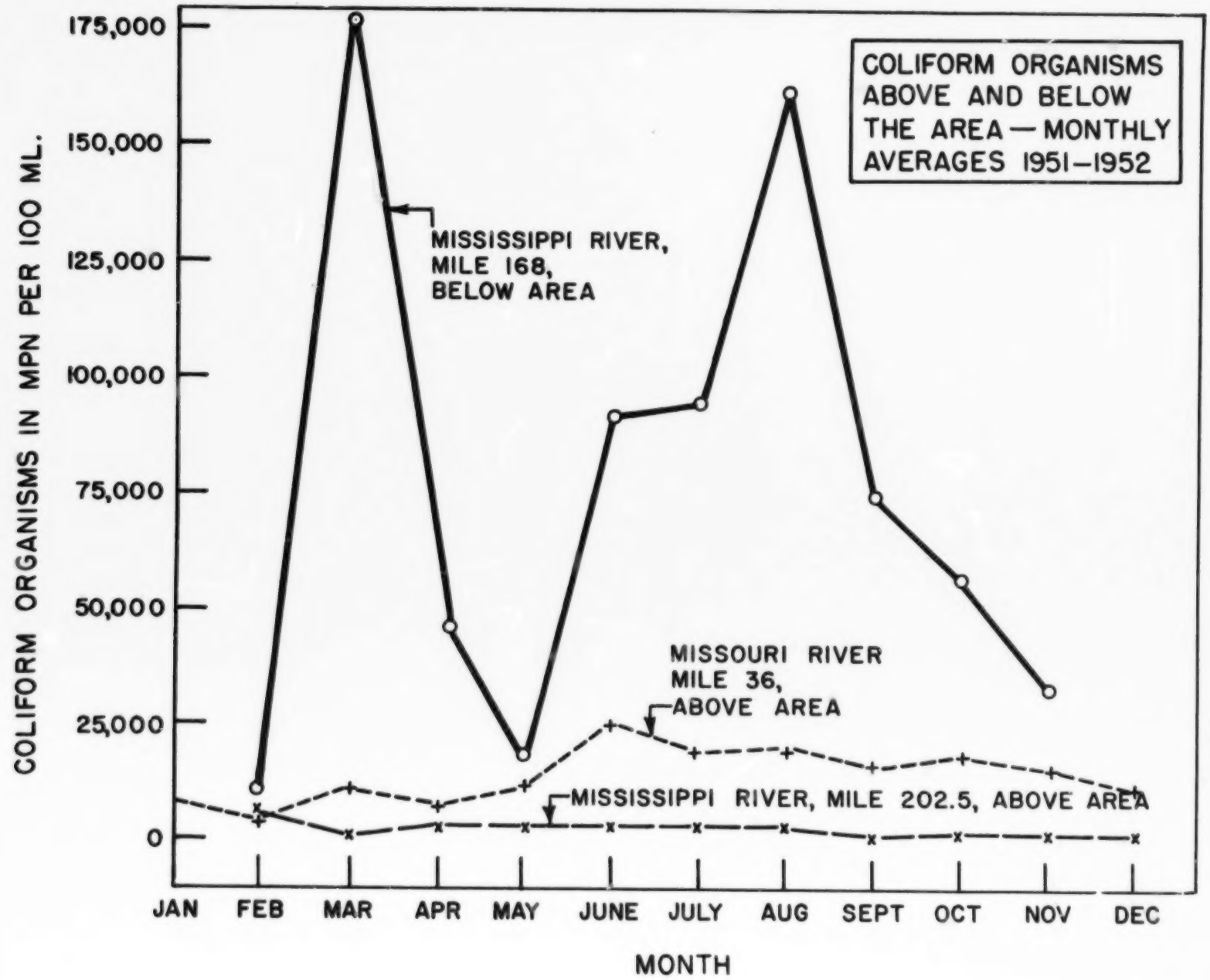

COLIFORM ORGANISMS IN MPN PER 100 ML.
175,000
150,000
125,000
100,000
75,000
50,000
25,000
0
COLIFORM ORGANISMS ABOVE AND BELOW THE AREA — MONTHLY AVERAGES 1951–1952
MISSISSIPPI RIVER, MILE 168, BELOW AREA
MISSOURI RIVER MILE 36, ABOVE AREA
MISSISSIPPI RIVER, MILE 202.5, ABOVE AREA
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
MONTH

FIGURE 2

42

Metropolitan Area and four downstream taking water from the Mississippi are subjected to the effects of pollution from the Metropolitan Area.

East St. Louis and Interurban Water Company (Illinois)

The treatment plant serving this Illinois water supply takes water from the east side of the Mississippi River below the Wood River-Hartford-Roxana, Illinois, portion of the Metropolitan Area. Tastes due to phenol-like compounds, mercaptans, and nitrogen bases, all typical of refinery wastes, have been a major problem for many years. Special treatment facilities for application of chlorine dioxide have been provided to combat this problem, but have not been completely successful. Consumers' frequent complaints show their dissatisfaction with the situation.

City of St. Louis, Chain of Rocks Supply (Missouri)

The City's Chain of Rocks water treatment plant pumps water from the Mississippi near the Chain of Rocks Highway Bridge, about five miles below the mouth of the Missouri. The plant is served by three intake structures, one near the west bank of the river, one approximately in the middle, and one near the east bank. The east intake, installed in 1913 at a cost of $491,000, has virtually been abandoned because of tastes in water pumped from that side of the river below the Wood River-Hartford-Roxana area. Records of use of this intake are not available, but it is reported to be "used very infrequently."

Illinois State Prison, Menard Division, Supply (Illinois)

Water for the Illinois State Prison at Menard, Illinois, serving 2,500 to 2,600 persons, is taken from the Mississippi River near the Chester Highway Bridge. This is about 59 river miles below the Jefferson Barracks Highway Bridge. Essentially all pollution from the St. Louis Metropolitan Area enters the river upstream from the Jefferson Barracks Bridge. Even at minimum river flow, when water velocities are lowest, the time of water travel from the bridge to the water plant intake is only little more than one day. Although the prison water intake may be considered relatively far below the entry of pollution from the Metropolitan Area in terms of distance, it is relatively close in terms of time. Any effects of pollution from the Metropolitan Area on water quality at the prison must be judged in terms of fresh rather than distant pollution.

Daily laboratory examinations, including determination of most probable numbers (M.P.N.) of coliform organisms, are made on both raw and treated water by prison personnel. In addition, samples of raw water

are submitted about once per month to the Illinois Department of Public Health Laboratory at Springfield for bacteriological examination.

The monthly average presumptive coliform results taken from the prison laboratory records for 1956 and 1957 are shown in Figure 3.

Average monthly coliform results for 1952 in the Mississippi River at mile 168.0 were taken from the Bi-State Agency Report. Death rates for coliform organisms found in several other rivers were applied to these monthly averages to compute the coliform concentrations that would reach the prison intake under the 1952 conditions. These results are also plotted in Figure 3.

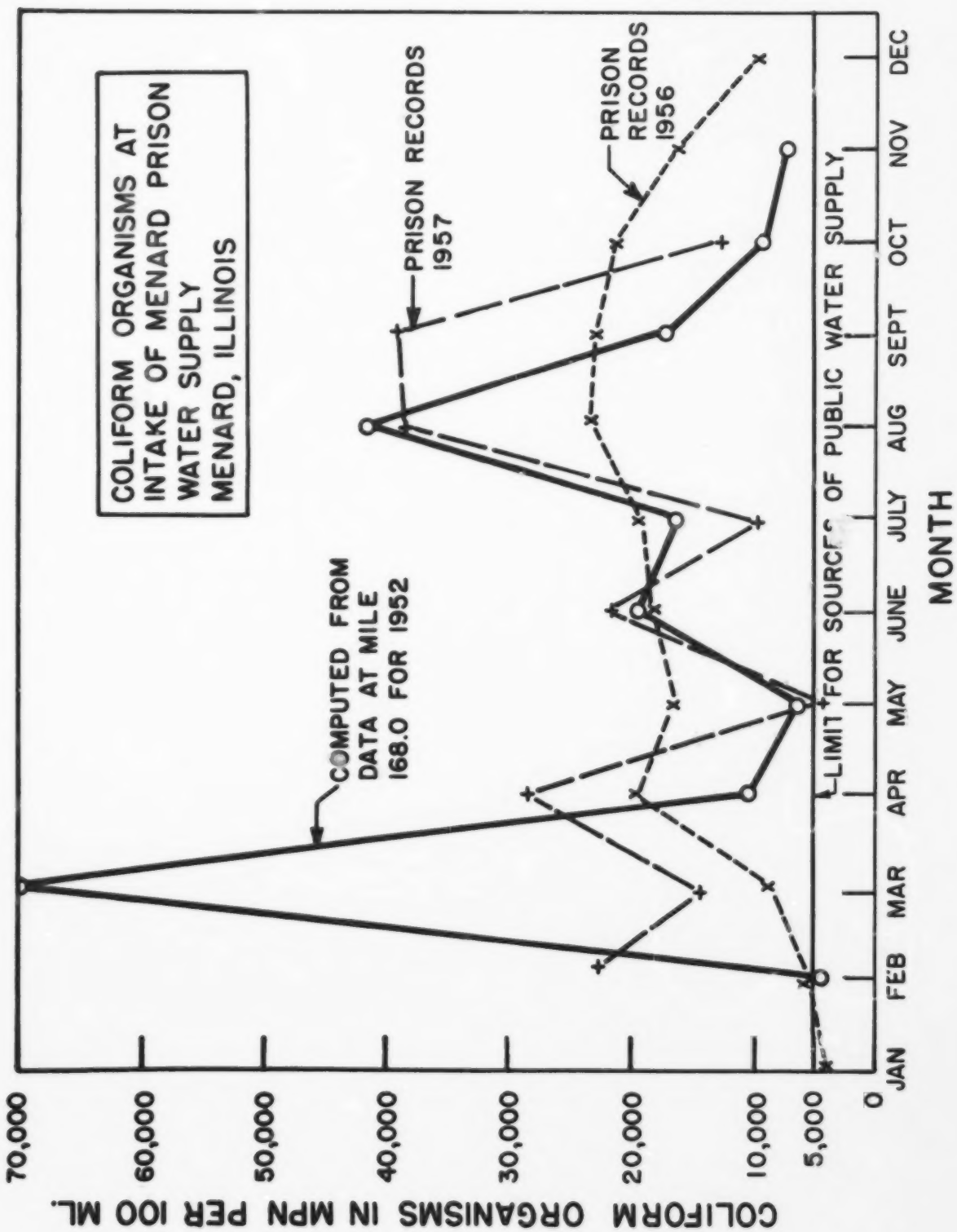
The results are not necessarily expected to agree closely among themselves from month to month. They are dependent on patterns of monthly river flow, which do not repeat themselves from year to year. The results do agree, however, within the limits expected of such data for different years. Most of them tend to fall in the range of 5,000 to 25,000 per 100 ml. of water. The averages for the three years are in satisfactory accord, with 15,300 for 1956, 21,200 for 1957 and 20,200 for 1952. The yearly average for the 1957 prison data and that for the 1952 computed data are essentially the same.

It is probable that all averages tend to be low rather than high. Those from the prison data include a number of indeterminate values for samples containing high coliform concentrations, which are reported as equal to or greater than the recorded numbers. If actual quantitative values had been obtained on such samples, the averages undoubtedly would have been higher. The computed values make no allowance for the usual downstream initial increase in coliform concentrations to a peak, which occurs before the normal die-away pattern becomes effective. Allowance for the peak would have yielded higher computed values. Results on raw water samples submitted to the Illinois Department of Public Health one day each month indicate generally higher coliforms than do the monthly averages. Of 9 samples submitted during 1957, 5 contained 240,000 or more per 100 ml., 2 had 69,000, and only 2 had 24,000 or less. The average for the 9 samples was 140,000 per 100 ml.

The data show conclusively that the bacterial contamination exceeds the limit of 5,000 per 100 ml. established for water used as a source of public supply with the type of treatment provided at the Menard Prison. Only for one month of each year was the average MPN below this limit.

It is recognized that a modern, fully equipped water treatment plant, operated at maximum efficiency at all times, can produce bacteriologically safe water from raw water containing more than 5,000 per 100 ml. of coliform organisms. However, a breakdown in crucial equipment, or a slip in operating procedure can permit bacterial contamination, with its threat of disease to the consumers, to pass through the treatment plant. The greater the bacterial concentration in the raw water, and the closer the intake, in terms of time, to the point of

FIGURE 3


COLIFORM ORGANISMS AT
INTAKE OF MENARD PRISON
WATER SUPPLY
MENARD, ILLINOIS
COMPUTED FROM
DATA AT MILE
168.0 FOR 1952
PRISON RECORDS
1957
PRISON
RECORDS
1956
LIMIT FOR SOURCE OF PUBLIC WATER SUPPLY
COLIFORM ORGANISMS IN MPN PER 100 ML.
70,000
60,000
50,000
40,000
30,000
20,000
10,000
5,000
0
JAN FEB MAR APR MAY JUNE JULY AUG SEPT OCT NOV DEC
MONTH

sewage discharge, the greater the health hazard when efficiency of treatment fails.

There is evidence that the Menard water plant has not always succeeded in removing all sewage bacteria from the highly contaminated river water. The prison laboratory records show presumptive positive results for coliform organisms in the finished water on 8 days in 1954, 10 in 1955, none in 1956, and 10 in 1957.

The Advisory Board for the 1951-1952 study of pollution in the Metropolitan Area developed water quality objectives as a basis for pollution control. Among these are limits of an average of 2 parts per billion (ppb) of phenol or phenol equivalents with no single maximum exceeding 5 ppb. One reason for adopting the phenol limits was to prevent taste and odor in drinking water. Phenols are not determined at the Menard plant, but 8 sets of samples were obtained at mile 109.5 in October and November 1952. The average of all sample results was 9 ppb. Six of the eight results were greater than 5 ppb, and on one day the value was 18 ppb.

Considerable difficulty with taste and odor was encountered in the prison water supply before facilities for maintaining free residual chlorine were installed.

The plant was visited in December 1957 in connection with the preparation of this report. A few small, grey particles of grease, similar to those found in sewage, garbage, and meat packing plant wastes were noticed on the water surface of the filters. The operator reported that the level of the raw water intake had been lowered several feet in the river in September 1957. Before that time chicken feathers frequently entered the filters. Prophylactic rubber articles also had entered the filters occasionally.

Chester Water Supply (Illinois)

The Chester water plant, serving this Illinois town of 5,389 population, (1950 census), takes water from the Mississippi River about 0.6 of a mile below the Menard Prison intake. The water quality at the Chester intake is essentially the same as that at the prison intake. Conclusions regarding bacterial quality, phenol content, and taste and odor of the prison raw water supply apply to the Chester supply. Facilities for applying free residual chlorination to combat taste and odor had to be provided here. Taste problems account for the fact that this plant became the second in Illinois at which free residual chlorination was adopted. This practice has been followed here, without interruption, longer than it has at any other plant in the State.

Of 57 raw water samples submitted to the Illinois Department of Public Health Laboratory at Springfield since 1951 about 86 per cent yielded MPN's of more than 5,000 coliforms per 100 ml., 74 per cent

yielded more than 20,000 per 100 ml., and 37 per cent yielded 240,000 or more. The average for all samples was 112,000 per 100 ml. This is in reasonable agreement with the average of 140,000 per 100 ml. on the 9 samples of raw water submitted to the health department by the Menard Prison in 1957.

Recent records do not indicate that coliform organisms have occurred in the finished water. The plant is equipped for application of a far greater variety of chemical water treatment processes than is provided at the majority of water plants. These facilities and extraordinary care in operation account for the excellent bacterial quality of the treated water.

The intake is not so deep as that for the Menard Prison, and greater difficulties have been encountered with floating material from upstream pollution. There were many small grease particles on the surface of the water in the filters at the time of the December 1957 visit. The walls of the filters above the water surface were coated with grease particles. Chicken feathers and what appeared to be small entrails were observed in the filters. The operator reported that these materials enter the plant in the raw water regularly. He also stated that prophylactic rubber articles enter the filters on an average of about once a month.

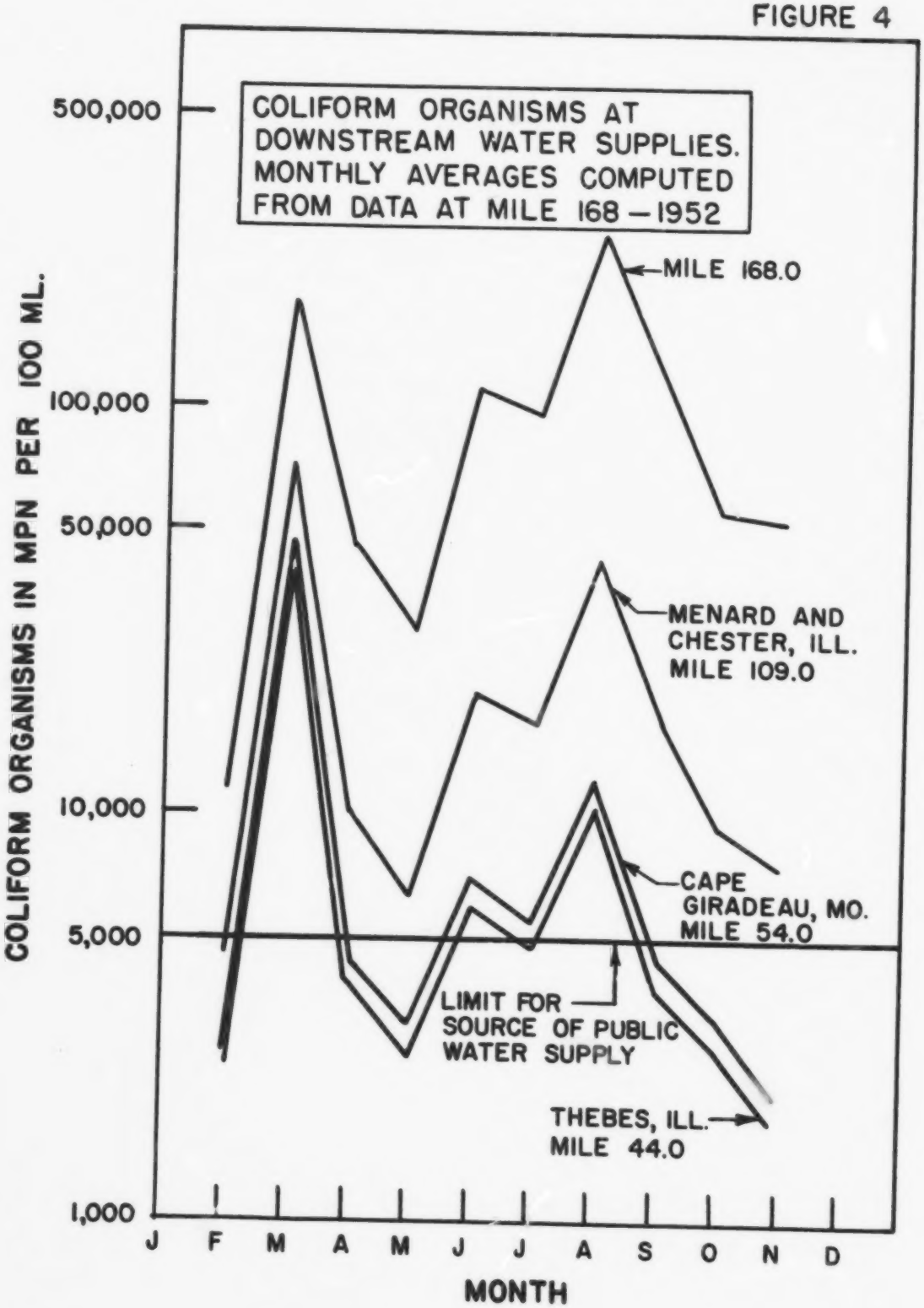
Cape Giradeau Water Supply (Missouri)

The Missouri Utilities Company water plant serves the 21,578 (1950 census) population of Cape Giradeau. Raw water is taken from the river near mile 54.0, about 115 miles below the Jefferson Barracks Highway Bridge.

Records of coliform content of the river water at this point in 1951-1952 are limited. Results of two samples collected in November 1952 are contained in the Bi-State report. The MPN's were 30,300 and 19,700 per 100 ml. Seven raw water samples submitted to the Missouri Division of Health during November 1957, yielded coliform MPN's in the range of 24,000 to 350,000 per 100 ml., with an average of 188,000. The range on 19 samples in December 1957, was 4,300 to 1,100,000 per 100 ml., with an average of 128,000. The observed values generally are higher than computed monthly averages discussed below.

The method used for computing 1952 monthly averages at the Menard Prison and Chester intakes was employed for the raw water at Cape Giradeau. The computations make no allowance for sewage pollution added to the river below the St. Louis area, but indicate rather the residual of the bacterial contamination immediately below the St. Louis Metropolitan Area that persists to Cape Giradeau. The results are presented in Figure 4. They show improvement over the Menard-Chester values because of the longer time of water travel from St. Louis to Cape

FIGURE 4


COLIFORM ORGANISMS AT DOWNSTREAM WATER SUPPLIES. MONTHLY AVERAGES COMPUTED FROM DATA AT MILE 168 – 1952
COLIFORM ORGANISMS IN MPN PER 100 ML.
500,000
100,000
50,000
10,000
5,000
1,000
MILE 168.0
MENARD AND CHESTER, ILL. MILE 109.0
CAPE GIRADEAU, MO. MILE 54.0
LIMIT FOR SOURCE OF PUBLIC WATER SUPPLY
THEBES, ILL. MILE 44.0
J F M A M J J A S O N D
MONTH

Giradeau. At minimum flows this would be about two and one-half days. For 4 of the 10 months involved the raw water coliform organism MPN exceeded the 5,000 per 100 ml. limit. The 10 month average was 8,800 per 100 ml. The contamination of this raw water must be considered a health hazard if either equipment or operation fails for even a short time. The operator stated that finished water samples, submitted to the State once a month, occasionally yielded positive results for coliform organisms.

Only 2 sets of samples for phenol determination were collected here in November 1952. One contained 4 ppb of phenol and the other 14 ppb. Even these limited data indicate that the limits established by the Advisory Board for phenol or phenol equivalents are exceeded at times. Facilities for free residual chlorination to combat taste and odor have been provided at the plant.

The operator did not report any problems caused by floating solids from upstream pollution.

Thebes Water Supply (Illinois)

Water for the small Illinois town of Thebes (573 population) is taken from the Mississippi at approximately mile 44.0, about 125 miles below Jefferson Barracks Highway Bridge.

The computations based on 1952 data indicate that bacterial contamination exceeds the 5,000 per 100 ml. limit for a source of public water supply even this far below the St. Louis Metropolitan Area. Monthly averages exceeded 5,000 per 100 ml. for 3 of 10 months (Figure 4), with an average for the 10 months of 7,900 per 100 ml.

Bacterial contamination has occurred in the Thebes treated water a number of times. Samples of the treated water submitted to the Illinois Department of Public Health laboratory have yielded the following positive results for coliform organisms, in terms of percentages of the total number of 10 ml. portions of water examined.

Occurrence of Contamination in Treated Water-Thebes, Illinois

Year	Positive 10 ml. Portions-per cent
1950	3.9
1951	6.1
1952	1.7
1953	0.0
1954	0.0
1955	3.0
1956	4.9
1957	6.0

Organics in Water Supplies

Previous examinations of water supplies located just above St. Louis by the carbon filter technique have shown that the waters of both the Mississippi and the Missouri contain appreciable quantities of highly odorous organic compounds. Several of these compounds are of industrial origin. They are not significantly reduced by normal water treatment methods, but pass through the treatment plants in the finished water.

A number of industries in the Metropolitan Area discharge wastes containing organic compounds of a nature similar to those found upstream. These wastes add to the load of odorous organic compounds of this type which is imposed on the downstream water supplies.

Industrial Water Supplies

The river serves as an important source of industrial water supply. In 1952 five large plants were using over 40 million gallons of water per day for industrial processes. At that time existing and anticipated use for cooling water at electric power plants was over one and one-half billion gallons per day or 6 per cent of the minimum river flow.

Time was not available for investigating actual effects of pollution on industrial supplies for inclusion of available information in this report. Many industries require process water of a high quality that can be achieved only by treatment. Existing pollution of the Mississippi in the Metropolitan Area can render treatment of river water for certain industries both difficult and costly. This imposes a handicap on the area when competing for new industries with other areas having less polluted sources of industrial water.

Recreation

There are several major recreational uses of the Mississippi River in the St. Louis Metropolitan Area that are typical of any large stream in or near a major center of population.

Scenic Values

Any large body of water has a natural attraction for the majority of people, who obtain aesthetic pleasure from the view afforded by the water. The pleasure of most viewers is reduced if they are aware that the water is polluted. Those who have seen, close at hand, the floating evidence of pollution on the Mississippi in the vicinity of the Metropolitan Area are apt to lose some of their enthusiasm for the beauty of the river even when viewed from a distance.

The floating material was especially noticeable in the western half of the river during a boat trip for observation of conditions in December 1957. Chicken feathers and entrails, paper, patches of grease, and prophylactic rubber articles were obvious on and just below the surface of the water. An irregular, but continuous, trail of floating vegetable matter and grease patches extended from the mouth of the Old Mill Creek sewer at least as far downstream as Jefferson Barracks, a distance of 9 miles. Especially noticeable, in addition to the grease, were citrus fruit peels and leafy vegetables which appeared to have escaped the disintegrating action of the city's garbage grinding equipment. Hundreds of gulls hovering over the river and dipping into it from time to time attested to the presence of a plentiful supply of food at the surface of the water. Near the lower end of this section the surface of the water over the entire width of the river was covered with an oil sleek typical of either sewage or oily waste pollution.

Oil marks line the riprap on the banks of the Chain of Rocks Canal below the navigation lock. The water of this section of the canal appears black and rising gas bubbles indicate the presence of sludge on the bottom of the canal. Rocks along the Missouri bank between River Des Peres and Jefferson Barracks Highway Bridge appear rusty with iron deposited from industrial waste.

The objectionable floating materials will be brought forcibly to public attention when the proposed Mississippi River Highway and especially the Municipal Waterfront Development are completed.

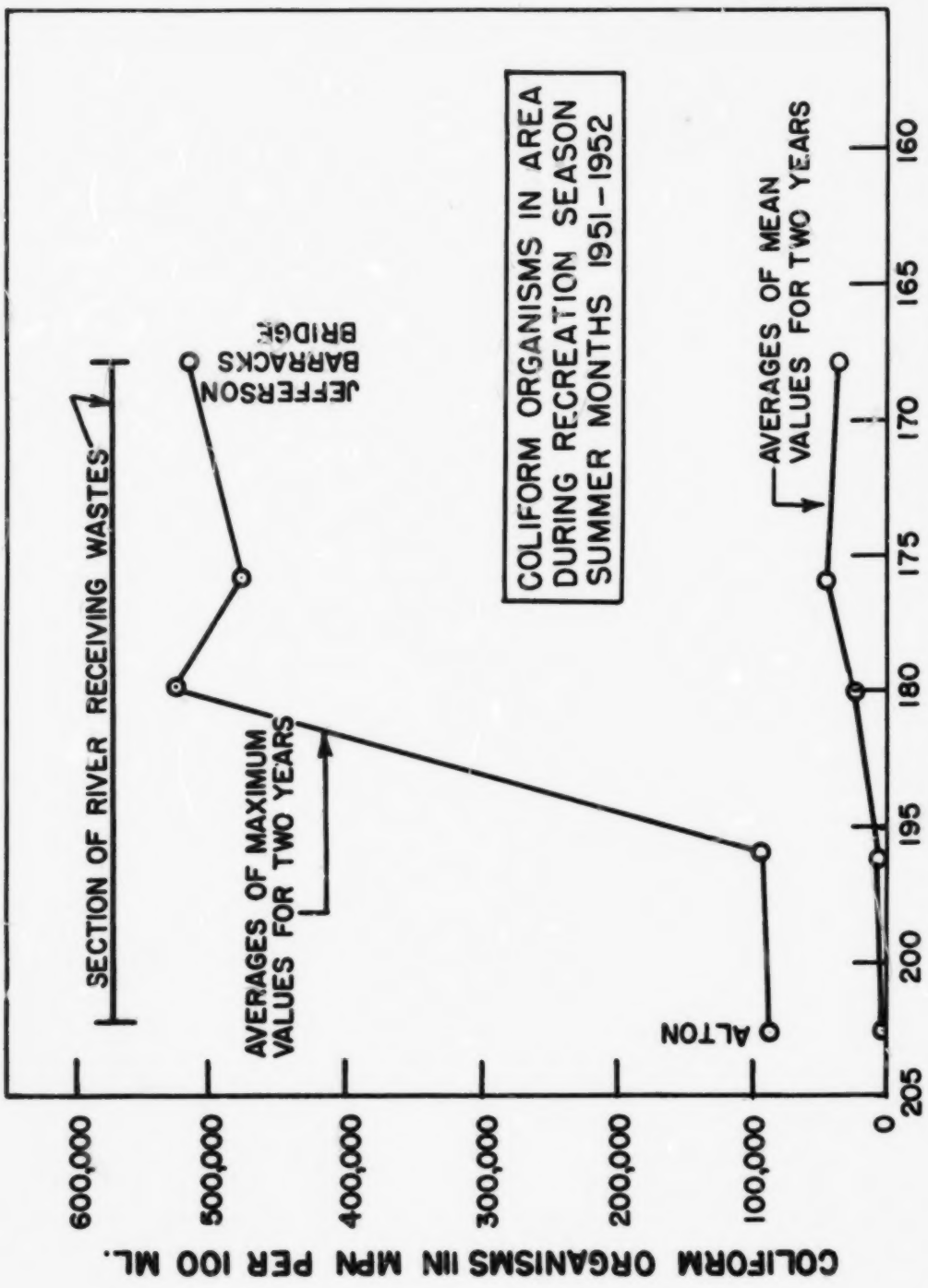
The objectives of the Bi-State Agency Report state that adequate protection of the river against pollution requires substantially complete removal of floating solids from sanitary sewage and storm water, and reduction of oils and floating solids from industrial wastes to a point where they will not coat hulls of water craft, injure fish or wildlife, or adversely affect public or private recreational uses. This should be accomplished by reducing the discharge of such materials to a point where, after initial dilution, the stream shall be free of noticeable floating solids, oil, grease, and sleek.

Pleasure Boating

The river is used for pleasure boating, especially on summer holidays and week-ends. Most of the pleasure boaters use outboard motor boats which are hauled to the river on trailers, often from distant points. The City of St. Louis has provided a concrete ramp for unloading and loading such pleasure crafts. This ramp is near the Veterans Memorial Bridge.

Those who use the river for boating in and below the Metropolitan Area are exposed to the health hazards of intimate contact with water contaminated with sewage. Figure 5 indicates the levels of coliform

FIGURE 5


COLIFORM ORGANISMS IN MPN PER 100 ML.
600,000
500,000
400,000
300,000
200,000
100,000
0
205
200
195
180
175
170
165
160
MILES ABOVE MOUTH OHIO RIVER
SECTION OF RIVER RECEIVING WASTES
JEFFERSON BARRACKS BRIDGE
ALTON
AVERAGES OF MAXIMUM VALUES FOR TWO YEARS
AVERAGES OF MEAN VALUES FOR TWO YEARS
COLIFORM ORGANISMS IN AREA DURING RECREATION SEASON SUMMER MONTHS 1951-1952

organisms to which boaters are exposed in the Metropolitan Area. These data are taken from the Bi-State Agency Report for the summer months of 1951 and 1952. The sampling stations extended from Alton, Illinois to one mile below Jefferson Barracks Highway Bridge. In the lower portion of this stretch the average coliform concentration was around 40,000 per 100 ml. This means that each drop of water splashed from the prow of a boat into an occupant's face would contain about 20 "sewage bacteria." Occasional maximum concentrations in the lower portion of the stretch were about 500,000 per 100 ml. The water at such times was roughly equivalent to 1 volume of sewage in 200 volumes of water. The increasing popularity of water skiing is rapidly multiplying the numbers of persons who, when they fall into the water and submerge, receive even greater exposure to the contaminated water than do the boaters.

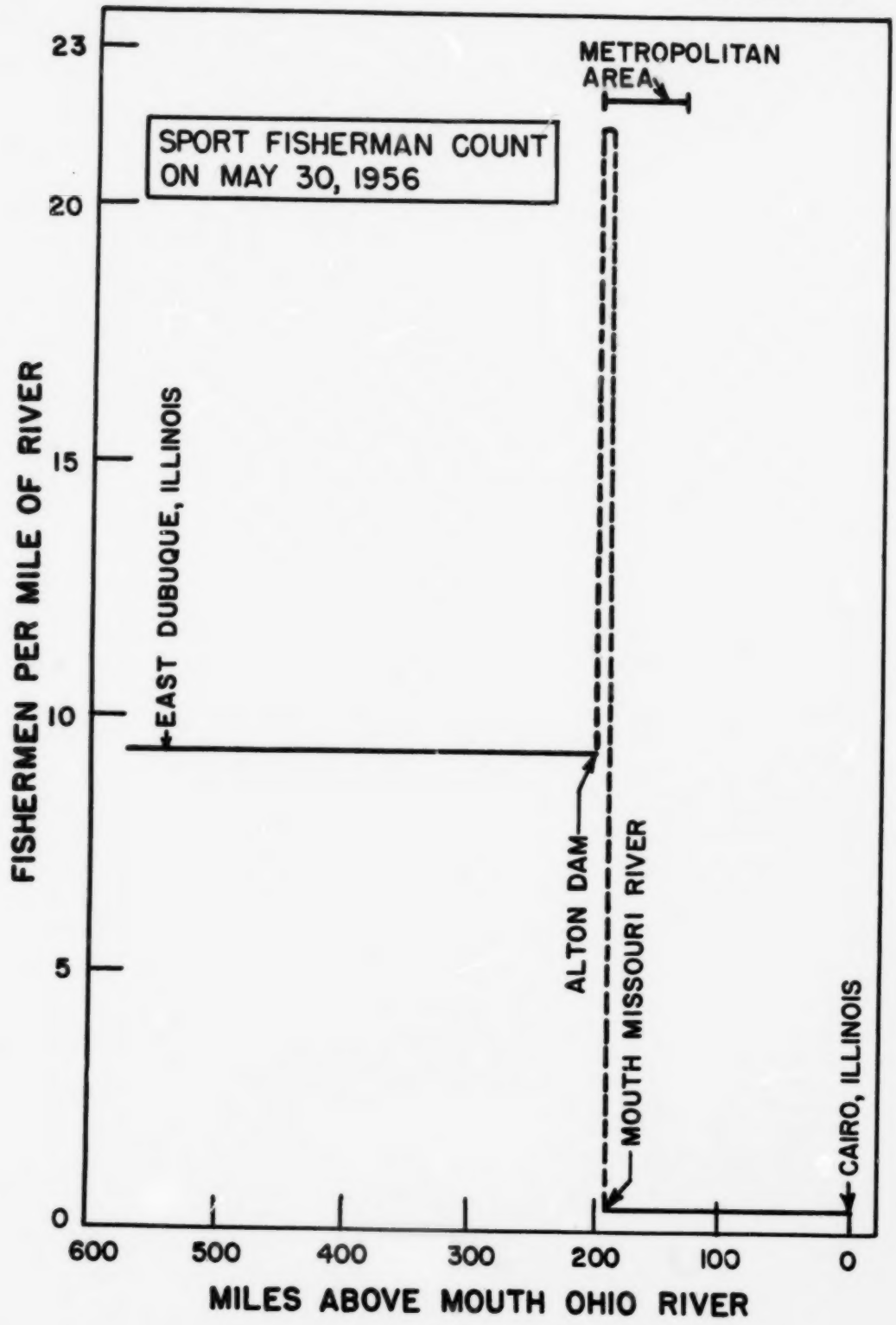
Boaters in this section not only are exposed to health hazards, but they are offended by the floating pollutional materials described in the preceding section. Owners who moor boats at river docks within the Metropolitan Area complain that paint on the boats is ruined by floating oil.

Sport Fishing

There are individuals who seek both pleasure and food by fishing from the banks of the river or from small boats. Those who fish in the Metropolitan Area and for some distance downstream are subjected to the health hazards of intimate contact with contaminated water similar to the hazards to the boaters. They undergo the additional hazard of handling fish that have been contaminated by bacteria of sewage origin.

While a few expose themsleves to the health hazards of fishing in this portion of the river, there is little use of the stream between the Metropolitan Area and the mouth of the Ohio River for sport fishing. The taste in the flesh of fish taken from the river may be a cause of the small amount of sport fishing in this area. This problem will be covered in more detail in the section on commercial fishing. The difference between upstream and downstream sport fishing is best illustrated by a recent check on numbers of sport fishermen made by plane from East Dubuque to Cairo, Illinois. This survey was conducted under the supervision of the Illinois Natural History Survey Division on Memorial Day, May 30, 1956. In the pooled section of the river from East Dubuque to Alton, Illinois, a distance of 377 miles, 3,495 sport fishermen, or 9.3 per mile, were observed. From Alton Dam to the mouth of the Missouri River, a distance of 8 miles, 173 sport fishermen, or 21.6 per mile were counted in this open stretch of fast flowing water. Most of them were fishing on the west side of the stream, which is across the river from the refineries at Wood River, Hartford and Roxana, Illinois. From the mouth of the Missouri to Cairo, Illinois, a distance of 195 miles, only 81 sport fishermen, or about 0.4 per mile, were observed. These data, which speak for themselves, are shown graphically in Figure 6.

FIGURE 6


SPORT FISHERMAN COUNT
ON MAY 30, 1956
METROPOLITAN AREA
EAST DUBUQUE, ILLINOIS
ALTON DAM
MOUTH MISSOURI RIVER
CAIRO, ILLINOIS
FISHERMEN PER MILE OF RIVER
0
5
10
15
20
23
600
500
400
300
200
100
0
MILES ABOVE MOUTH OHIO RIVER

Navigation

The Mississippi River has been an important inland waterway since this country was first settled. Not only St. Louis but many other cities hundreds of miles upstream are dependent on the river for economical transportation of goods and materials.

Those who engage in navigation are subjected to the health hazards and visual nuisances described in the section on pleasure boating. Costs of navigation are increased by the effects of pollution on operation and maintenance of floating and fixed equipment and navigation aids.

Commercial Fishing

The Mississippi River from the St. Louis Metropolitan Area to the mouth of the Ohio River has become notorious for the taste of fish taken from this 200 miles of stream. Commercial fishermen have almost abandoned the river from St. Louis to Cairo.

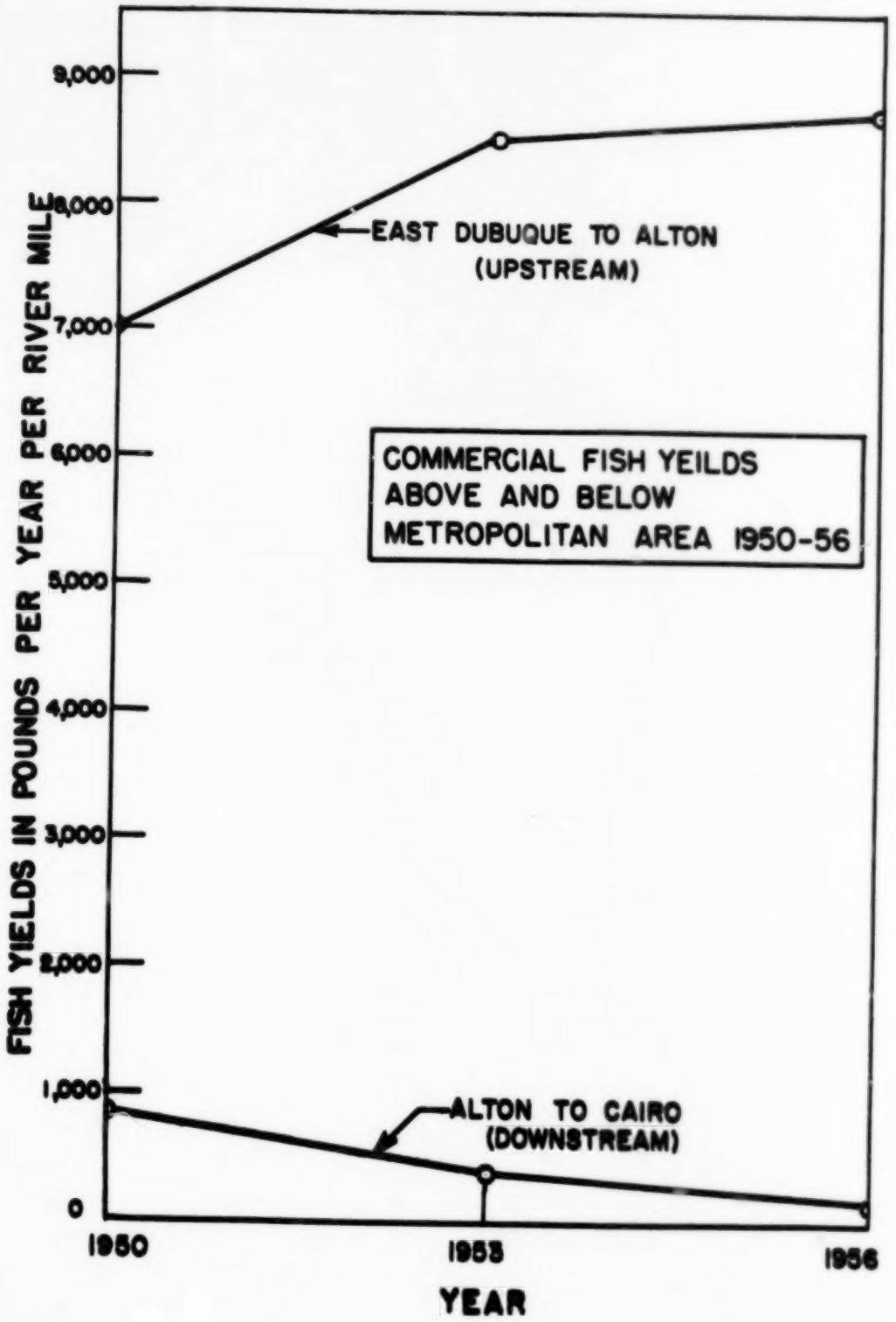
Comparative Fish Yields Above and Below Alton

A representative of the Illinois Natural History Survey Division, who maintains regular records of fish and fishing in the Mississippi River where it borders Illinois has records of only two commercial fishermen in this section who still are active on a major scale. One of these has acquired a fresh water pond in which he places fish taken from the river and leaves them for about two months to permit the taste to dissipate.

It has been claimed that better employment opportunities, availability of packaged frozen fish, and similar factors have played a part in reduced fish catches in the Mississippi below the Metropolitan Area. The validity of these claims are subject to serious question when catches above and below the Metropolitan Area are compared. The following records were supplied by the Illinois Natural History Survey. The years selected are those for which the records are believed to be most reliable. The data are for Illinois commercial fishermen only.

The data are shown graphically in Figure 7. The moderate increase in commercial fish yields above the Metropolitan Area indicates that commercial fishing in the upstream section of the river has not been affected by competetive factors. The increasing spread between the upstream and downstream yields is convincing. In 1950 the weight of fish per mile taken downstream was a little less than one-eighth of that taken upstream. By 1956 the downstream yield had dwindled to less than one-seventieth of the upstream yield.

FIGURE 7


9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
FISH YIELDS IN POUNDS PER YEAR PER RIVER MILE
EAST DUBUQUE TO ALTON
(UPSTREAM)
COMMERCIAL FISH YEILDS
ABOVE AND BELOW
METROPOLITAN AREA 1950-56
ALTON TO CAIRO
(DOWNSTREAM)
1950
1953
1956
YEAR

Commercial Fish Yields Above and Below Metropolitan Area

Year	Fish Catches Per Year			
	East Dubuque to Alton		Alton to Cairo	
	Million Pounds	Pounds per Mile	Million Pounds	Pounds per Mile
1950	2.62	7,000	0.169	840
1953	3.19	8,500	0.075	370
1956	3.28	8,700	0.025	120

The Natural History Survey data for 1956 show the value to Illinois commercial fishermen of fish taken between East Dubuque and Alton as $367,600, while that between Alton and Cairo was $3,200. This was equivalent to $975 per river mile above the Metropolitan Area compared to only $16 per mile below the area.

Anyone who discusses the situation with both laymen and informed fish technicians can not fail to be convinced that the taste in fish taken from the river below the Metropolitan Area is a major, if not the major, reason that commercial fisheries are small and continue to dwindle between St. Louis and Cairo.

Phenol-like Wastes

The best technically informed advice that has been received indicates that the taste in fish flesh is of a phenolic type rather than "oily" or "gassy' as it is popularly described by many laymen. During the 1951-1952 study phenol-like substances were determined on wastes from major waste sources in the Metropolitan Area. An average of 12,810 pounds per day was being discharged to the river at that time. This came from the sources tabulated below.

It is reported that much of the phenol equivalent from the Monsanto Village sewer is the chlorinated material, chlorphenol. In drinking water this material causes taste that is about 1,000 times as strong as that caused by an equivalent concentration of unchlorinated phenol. It appears reasonable that the chlorinated compound would similarly be more potent in imparting taste to fish flesh.

The average phenol equivalents for the winter months (December through March) in 1951-1952 were 1.8 ppb above the Alton and 12.0 ppb at mile 168.0 below all sources of phenol-like wastes from the Metropolitan Area. In pounds per day these values were 1,220 and 13,500 respectively. Assuming that there were no phenols in the Missouri River water, the difference between the phenol equivalents above and below the

area were 12,280 pounds per day. This figure varies by only 4.1 per cent from the total amount measured in the sewers.

Sources of Phenol Equivalents

Illinois	Pounds per Day	Per Cent of Total	Missouri St. Louis	Pounds per Day	Per Cent of Total
Wood River	890	7.0	Catlin St. Sewer	705	5.5
Roxana	1,490	11.6	Miscellaneous	35	0.3
Hartford	309	2.4			
E. St. Louis	274	2.1			
Monsanto Village	9,000	70.3			
Miscellaneous	107	0.8			
	12,070	94.2		740	5.8

Average values at mile 168.0 for summer and for intermediate months were 6.0 and 8.3 ppb. These data were obtained when average stream flows were very close to that for the winter months. The higher water temperatures of summer and intermediate months apparently caused more rapid reductions in phenols after entry to the river than occurred in winter.

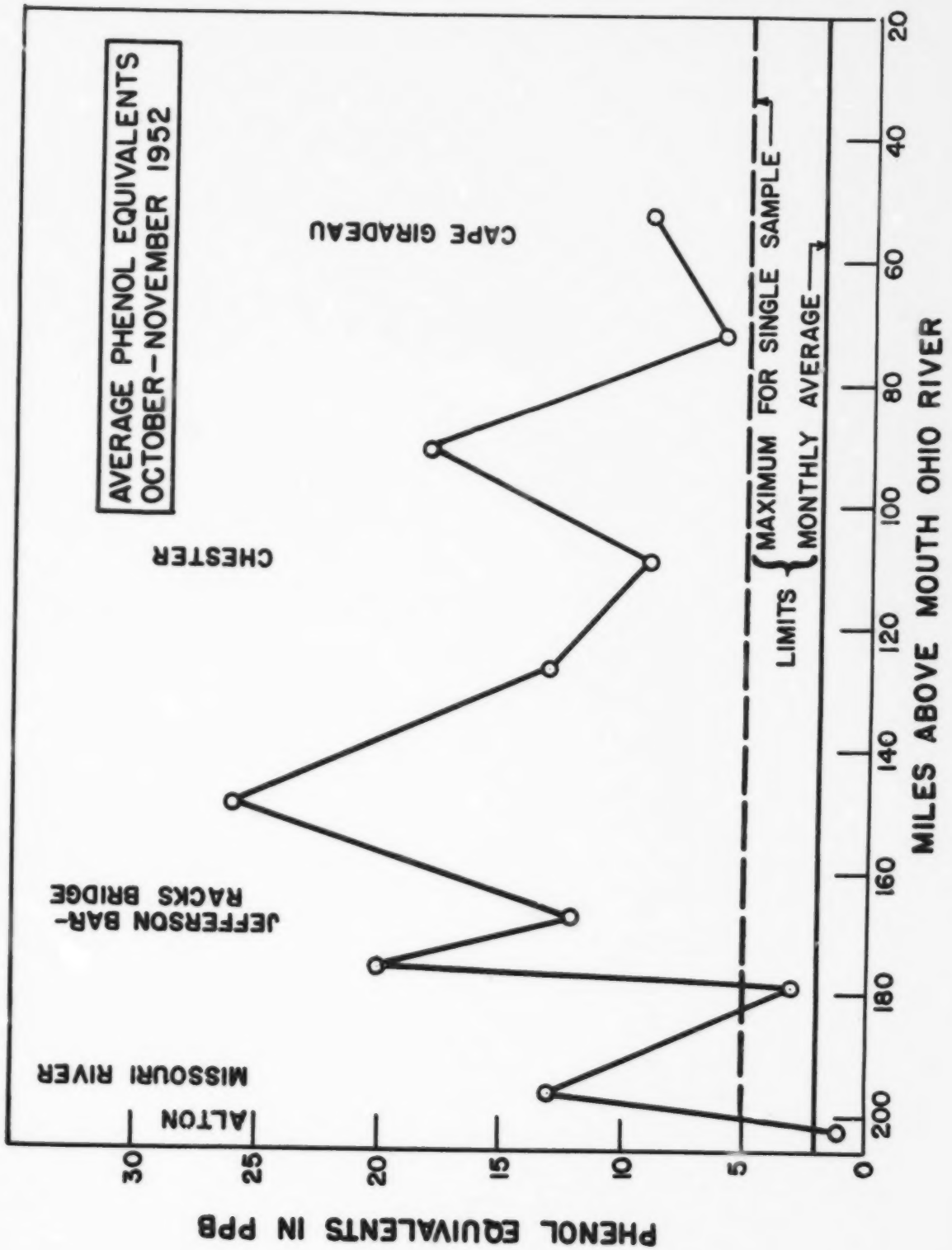
Average flows for all three periods were in excess of 200,000 cfs, which is greater than the average annual flow of 167,000 cfs for the Mississippi at St. Louis. When the river drops to its normal minimum of 40,000 cfs the average phenol equivalent concentration at mile 168.0 may be expected to rise to about 60 ppb. At such times phenol levels downstream could be several times greater than the values observed in 1952, which are discussed below.

Phenol data for the river below the Metropolitan Area are limited. In October and November 1952, samples were collected as far downstream as Cape Giradeau. Average flow of the river was 72,000 cfs. The average results obtained are plotted in Figure 8. It is obvious that phenol equivalents exceeded the limits established by the Bi-State Advisory Board for protection of water supplies and prevention of taste in fish.

Dissolved Oxygen

The Bi-State Agency report noted the occurrence of several samples in which dissolved oxygen (D.O.) was below 5.0 ppm. This is generally accepted as the minimum D.O. desirable to maintain good water quality and to assure optimum propagation and growth of a mixed fish population. The low D.O. values were obtained when river flows were high. It appeared

FIGURE 8


AVERAGE PHENOL EQUIVALENTS
OCTOBER–NOVEMBER 1952
CAPE GIRADEAU
CHESTER
JEFFERSON BAR-
RACKS BRIDGE
MISSOURI RIVER
ALTON
LIMITS
MAXIMUM FOR SINGLE SAMPLE
MONTHLY AVERAGE
PHENOL EQUIVALENTS IN PPB
MILES ABOVE MOUTH OHIO RIVER
0
5
10
15
20
25
30
20
40
60
80
100
120
140
160
180
200

that present organic wastes from the St. Louis Metropolitan Area might deplete the D.O. sufficiently to damage fish and aquatic life downstream when stream flows are low and water temperatures are high. If this should be the case it could be a factor contributing to the reduced fish yield below the Metropolitan Area.

The river below St. Louis was sampled only in October and November 1952. At that time 8 sets of samples were collected as far downstream as Chester and 2 sets as far as Cape Giradeau. The average stream flow at St. Louis was 71,900 cfs and average water temperature was 10.1°C. The average D.O. values are plotted in Figure 9. These data were used, with average biochemical oxygen demand (B.O.D.) values obtained at that time and with times of water travel computed from river cross sectional areas, to calculate deoxygenation and reaeration coefficients characteristic of this section of the Mississippi River.

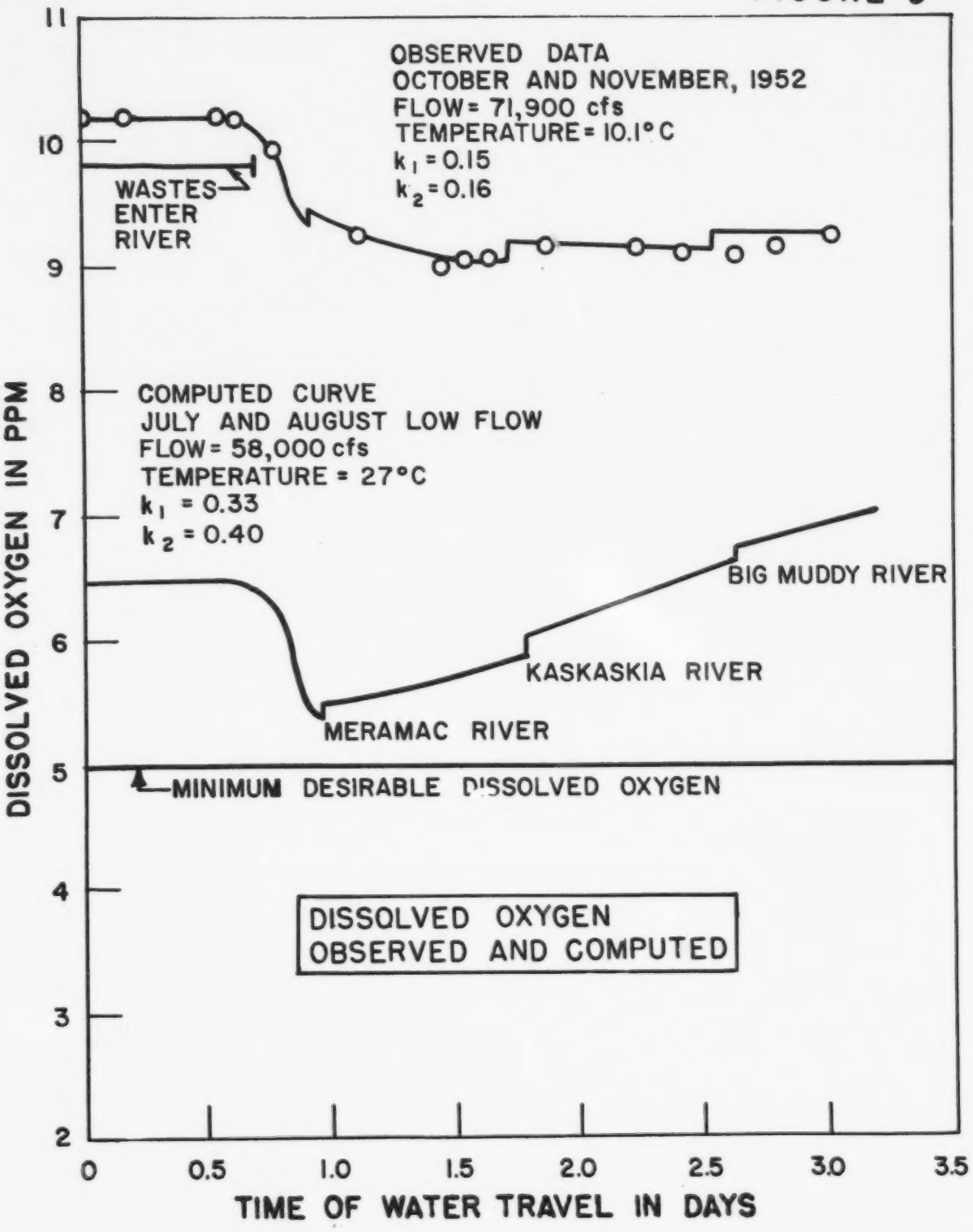
These computations, incidentally, revealed that the Metropolitan Area discharged wastes that caused a rather large immediate, or extremely rapid, oxygen demand in addition to the normal organic oxygen demand that has been described in the section on sources of waste. The immediate oxygen demand was 303,000 pounds per day, or about 36 per cent of the normal 5 day B.O.D. of the organic wastes.

Review of records of Mississippi River discharge at St. Louis for the months of July and August reveal that a consecutive 7 day minimum flow of 58,000 cfs will occur once in 10 years. A water temperature of 27°C, and upstream D.O. saturation of 80 per cent and B.O.D. of 1.86 ppm were selected from the Bi-State report as representative of July-August conditions. The computed river coefficients were adjusted for the changed river conditions and with the present estimated oxygen demand of the Metropolitan Area wastes, were used to compute an oxygen sag curve for a river discharge of 58,000 cfs. This curve is included in Figure 9.

The computed curve drops to 5.38 ppm of D.O. at its minimum point, just above the mouth of the Meramec River at mile 160.6. While this does not indicate damage to fish by D.O. depletion, it should be emphasized that the assumptions on which the curve is based are conservative. They involve average conditions, and make no allowance for peak discharges of wastes from the Metropolitan Area, nor for D.O. saturation less than 80 per cent upstream from the area. D.O. saturation as low as 65 to 70 per cent has occurred upstream. In addition, no allowance is made for a possible increase in the immediate oxygen demand of the wastes since 1952.

The probability that the computed curve is conservative is supported by recent data obtained by personnel of the City of St. Louis Municipal Testing Laboratory. Three samples were collected at St. Genevieve Ferry (mile 125.7) during July and August 1957. River flows were considerably in excess of 58,000 cfs, ranging from about 88,000 to 221,000 cfs at St. Louis. Despite the higher flows the three D.O.

FIGURE 9


OBSERVED DATA
OCTOBER AND NOVEMBER, 1952
FLOW = 71,900 cfs
TEMPERATURE = 10.1° C
k_1 = 0.15
k_2 = 0.16
WASTES ENTER RIVER
COMPUTED CURVE
JULY AND AUGUST LOW FLOW
FLOW = 58,000 cfs
TEMPERATURE = 27°C
k_1 = 0.33
k_2 = 0.40
BIG MUDDY RIVER
KASKASKIA RIVER
MERAMAC RIVER
MINIMUM DESIRABLE DISSOLVED OXYGEN
DISSOLVED OXYGEN OBSERVED AND COMPUTED
DISSOLVED OXYGEN IN PPM
TIME OF WATER TRAVEL IN DAYS
11
10
9
8
7
6
5
4
3
2
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5

results obtained by the city were in the range of 5.5 to 5.8 ppm, only 0.1 to 0.4 ppm above the computed minimum for 58,000 cfs.

It does not appear that D.O. depletion in the Metropolitan Area and downstream is damaging to fish at present. There is convincing evidence, however, that the situation is very near a borderline condition during periods of low flow and high temperature. Treatment facilities for wastes as numerous and complex as those in the area cannot be provided overnight. Unless corrective measures are initiated promptly excessive D.O. depletion may be added to the other damages imposed on the river by the Metropolitan Area.

Suspended Solids

Wastes from the sewers of the area were examined for suspended solids during the 1951-1952 study. The total from the combined area was found to be 458 tons, or nearly a million pounds, per day. The sources of these materials were almost equally divided between the two states, with 51.3 per cent from the Illinois side and 48.7 per cent from the Missouri side. The suspended solids results are reported on a dry basis. This should not be confused with the method of reporting the weight of garbage discharged by the City of St. Louis. In the section on sources of wastes the weight of the garbage was reported on the "green," or wet, basis. If the garbage solids were converted to the dry basis for comparison with the suspended solids they would be only a fraction of the weights previously discussed.

River velocities at St. Louis and downstream are high, with average velocity of 3 feet per second even at low flows. This prevents the suspended solids from settling close below the sewers to form large detrimental sludge beds. Instead the solids are carried downstream and settle only in quiescent areas along the banks, especially behind jetties and similar obstructions to free flow. During 1951-1952 deposits of suspended solids, particularly those from poultry processing wastes, were found as far as 100 miles downstream.

Sludge deposits may be harmful to fish life by intensifying oxygen depletion and by smothering bottom aquatic life on which fish feed. Organic suspended solids carried along in the flowing water contribute their share to the oxygen depletion of the water.

The Advisory Board established substantially complete removal of settleable solids and at least 45 per cent reduction of suspended solids in all sanitary sewage, storm water and deoxygenating industrial wastes as an objective for protection of water quality in the St. Louis Metropolitan Area.

Summary

The sewered population of the St. Louis Metropolitan Area increased about 10 per cent between January 1952 and midyear 1957. Of the estimated present total 1,254,000 sewered population about seven-eighths live on the Missouri side of the Mississippi River and one-eighth on the Illinois side.

Ground garbage discharged to the river by the City of St. Louis during the same period increased more than 200 per cent.

The total organic waste load, including that of industrial wastes, imposed on the river is estimated to have increased about 6 per cent. The total load is equivalent to the sewage from a population of about five and one-quarter million. About three-quarters of the load originates in Missouri and one-quarter in Illinois.

Other wastes include those from petroleum processing, phenol-like compounds, acids, metals, heavy chemicals and other industrial materials. Of these, the petroleum and phenolic wastes appear to be the most damaging to downstream water uses. All of the petroleum refining is in Illinois, and 94 per cent of the phenolic wastes enter the river from Illinois sources.

A serious aspect of the pollution of interstate waters resulting from discharge of these wastes in the Metropolitan Area is its effect on public water supplies. Water works affected are those of:

1. St. Louis, Missouri (Chain of Rocks Plant).
2. East St. Louis, Illinois (including adjacent communities served by the East St. Louis and Interurban Company).
3. Illinois State Prison, Menard Division.
4. Chester, Illinois.
5. Cape Giradeau, Missouri.
6. Thebes, Illinois.

The health hazard of excessive bacterial contamination of the river as a source of public water supply exists at the last four of the water works listed. Taste and odor of the treated water, inimical to the consumers and expensive to the communities, has been a severe problem in all six supplies. Floating grease particles, chicken feathers and entrails, and prophylactic rubber articles have entered the water treatment plants at Chester and the Menard Prison.

Users of the river for recreation are subjected to health hazards and visual nuisances. Pleasure boaters, water skiiers, and sport fishermen are exposed to direct contact with highly contaminated, sewage laden water in and downstream from the Metropolitan Area. In addition, floating grease, oil sleek, garbage and evidences of sewage pollution render the surface of the water objectionable in the Metropolitan Area. Boat owners complain of oil damage to paint.

The crews of boats engaged in navigation are exposed to the same health hazards and visual nuisances that affect the pleasure boaters. Costs of operation and maintenance for navigation are increased.

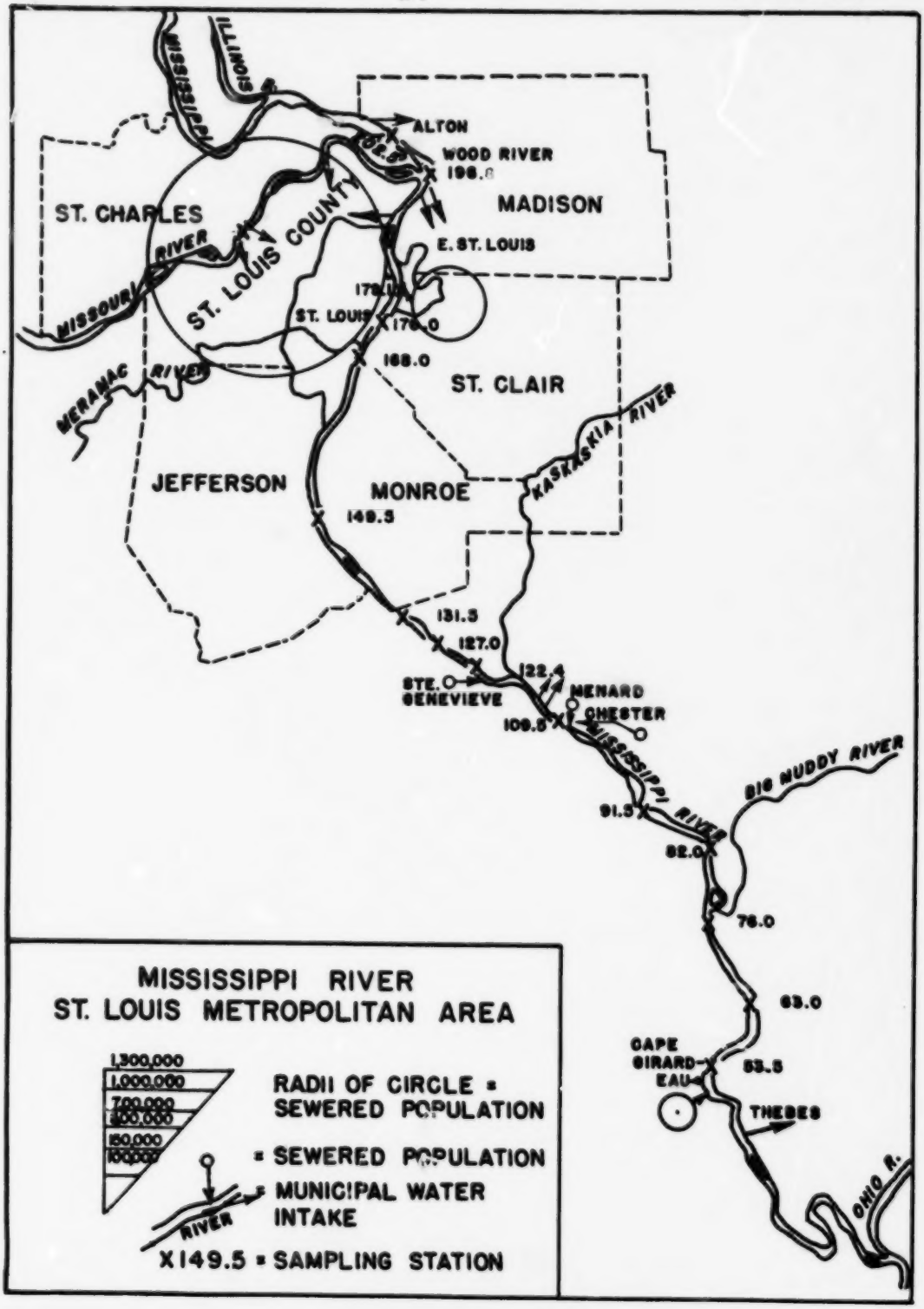
Both sport and commercial fishing in the river from the Metropolitan Area to Cairo, Illinois have almost ceased. A principal cause appears to be the taste imparted to fish flesh by industrial wastes. A recent Memorial Day holiday aerial survey revealed 173 sport fishermen in the 9 miles of river between Alton and the mouth of the Missouri River and only 81 in the 195 miles from the Missouri to Cairo at the mouth of the Ohio River. Annual commercial fish yields upstream in the East Dubuque to Alton, Illinois, section of the river increased 24 per cent from 1950 to 1956. Yields in the Alton to Cairo, Illinois section decreased 86 per cent. In 1956 the fish yields per mile below the Metropolitan Area were less than one-seventieth of those above the area. The average value of catches per river mile upstream was $975 compared to $16 downstream.

Marginal sludge deposits from discharge of excessive suspended solids have been observed as far as 100 miles downstream. The solids contribute to the depletion of dissolved oxygen of the river water, which is nearing an unsatisfactory level.

It is evident that pollution of the Mississippi River in and below the St. Louis Metropolitan Area constitutes pollution of interstate waters subject to abatement under the Federal Water Pollution Control Act as such pollution endangers the health and welfare of persons in states other than those in which the discharges contributing to such pollution originate.

APPENDIX

FIGURE I


ILLINOIS
MISSISSIPPI
ALTON
WOOD RIVER
198.0
MADISON
ST. CHARLES
ST. LOUIS COUNTY
E. ST. LOUIS
MISSOURI RIVER
ST. LOUIS
176.0
168.0
MERAMAC RIVER
ST. CLAIR
KASKASKIA RIVER
JEFFERSON
MONROE
149.5
131.5
127.0
122.4
STE. GENEVIEVE
MENARD
CHESTER
109.5
MISSISSIPPI RIVER
BIG MUDDY RIVER
91.5
82.0
78.0
63.0
CAPE GIRARDEAU
53.5
THEBES
OHIO R.
MISSISSIPPI RIVER
ST. LOUIS METROPOLITAN AREA
1,300,000
1,000,000
700,000
300,000
150,000
100,000
RADII OF CIRCLE = SEWERED POPULATION
= SEWERED POPULATION
= MUNICIPAL WATER INTAKE
RIVER
X149.5 = SAMPLING STATION